

## **METHOD OF CONNECTION TO A SPARK PLUG PRESSURE SENSOR**

### Technical Field

5           The present invention relates generally to a spark plug coil and pressure sensor electrical connection assembly.

### Background of the Invention

10           It is well known to provide a solid electrical connection between a high voltage source and a spark plug installed in an internal combustion engine, by way of a wire or the like. These electrical connections must withstand extreme environments such as vibration and high engine temperatures. However, such conventional electrical connections generally do not accommodate a spark plug assembly when it incorporates a pressure sensor. Notwithstanding this generalization, such an assembly including a connection where a pressure sensor is present is known and disclosed in  
15   U.S. Patent No. 6,119,667 entitled "INTEGRATED SPARK PLUG IGNITION COIL WITH PRESSURE SENSOR FOR AN INTERNAL COMBUSTION ENGINE" issued to Boyer et al.

          Boyer et al. disclose an integrated spark plug/ignition coil assembly with a pressure sensor for generating a signal indicative of a cylinder pressure in a  
20   cylinder of an internal combustion engine. The disclosed approach, however, requires additional electrical wiring to connect the pressure sensor to a connector of the integrated assembly for transmission of the pressure signal to an external control. This approach does not allow the spark plug to be easily separable from the ignition coil, impairing maintenance/repair.

25           It would therefore be desirable to provide a reliable electrical connection interface between a pressure sensor and an external connector of the overall spark plug/ignition coil assembly. The electrical connection would allow the ignition coil portion to be separable from the spark plug/pressure sensor portion, thereby allowing for serviceability and ease of attachment of the ignition coil to the  
30   spark plug/pressure sensor portion. It would also be desirable to provide an electrical connection that can provide electrical connectivity regardless of the angular

orientation of the spark plug/pressure sensor portion relative to the ignition coil portion.

There is therefore a need for an electrical connection system that overcomes one or more of the problems set forth above.

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### Summary of the Invention

An object of the present invention is to solve one or more of the problems set forth in the Background. An advantage of an electrical connection assembly according to the present invention is that it provides a readily  
10 separable/connectable structures configured for electrical conductivity. Another advantage is that it allows for a high degree of variation, relative to the angular alignment between the ignition coil portion and the spark plug/pressure sensor portion. A spark plug coil and pressure sensor assembly is provided for generating a spark to a cylinder of an internal combustion engine. The assembly includes a spark  
15 plug configured for mounting in a cylinder and a pressure sensor associated with the spark plug configured to detect a pressure in the cylinder and generate a pressure signal in response thereto. The assembly further includes a first electrically conductive ring connector configured to receive the pressure signal. The assembly still further includes a coil housing having a main axis having at least one electrically  
20 conductive leaf spring member. The leaf spring member is configured to resiliently engage the first electrically conductive ring connector over a first predetermined circumferential angle relative to the main longitudinal axis. The leaf spring is further configured, in one embodiment, for connection through the housing to an interface of the assembly. The interface may allow for conduction of the pressure signal to a main  
25 control.

A glow plug embodiment is also presented.

### Brief Description of the Drawings

The present invention will now be described by way of example, with  
30 reference to the accompanying drawings.

Figure 1 is a sectional view of a spark plug/ignition coil and pressure sensor assembly according to the present invention.

Figure 2A is an enlarged view of the spark plug/ignition coil and pressure sensor assembly of Figure 1.

Figure 2B is an enlarged perspective view of the first and second ring connectors of Figure 2A.

5                Figure 3 is a top view of the assembly.

Figure 4 is an enlarged section view of the assembly of Figure 1 taken substantially along lines 4-4 in Figure 3.

Figure 5 is an enlarged section view of the assembly of Figure 1 taken substantially along lines 5-5 in Figure 3.

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#### Detailed Description of the Preferred Embodiments

Referring now to the drawings wherein like reference numerals are used to identify identical components in the various views, Figure 1 illustrates a spark plug/ignition coil and pressure sensor assembly 10 having a connection feature in accordance with the present invention. Assembly 10 is configured to include a pressure sensor affixed to or in close proximity to a spark plug portion thereof.

Figure 1 is a simplified, sectional view of an assembly 10. Assembly 10 may be used for electrical energy delivery to an internal combustion engine, such as a spark-ignited internal combustion engine, or a diesel cycle internal combustion engine (*e.g.*, a glow plug). In the illustrated embodiment, assembly 10 is configured to provide a spark to a cylinder of an internal combustion engine (engine not shown).

With continued reference to Figure 1, assembly 10 is generally elongated, having a main axis designated "A." Assembly 10 includes a transformer 12 and a spark plug 30.

Transformer 12 is configured as a step-up transformer, taking a relatively low voltage (*e.g.*, a conventional 12-volt battery voltage of an automotive vehicle) and transforming it to a sufficiently high level to be applied to spark plug 30 so as to cause a spark across a spark gap thereof (*e.g.*, such high voltage may be in the range of 15-30 kV). Transformer 12 comprises a centrally-disposed, relatively high magnetic permeability magnetic core 14, a primary coil 16, a secondary spool 18 wound with a secondary coil 20, a housing 22, a substantially rigid outer shell 24 and

an interface 26. Core 14, primary coil 16, secondary spool 18 and secondary coil 20 are known generally in the art, and will not be described in any greater detail herein.

Housing 22 is configured to retain transformer 12, and is formed of electrically-insulating material.

5                Shell 24 may be formed of any suitable rigid material, such as steel or the like. As shown, shell 24 is formed of electrically conductive material, *e.g.*, for grounding purposes.

Interface 26, in the illustrated embodiment, is configured to receive a corresponding mating connector for the input/output of electrical signals to and from a  
10                central controller, such as an engine control unit (ECU) or the like. Such signals may include an electronic spark timing (EST) signal (*i.e.*, a dwell signal), a power signal, and a pressure signal. The latter two signals will be described in greater detail hereinafter.

With continued reference to Figure 1, spark plug 30 is configured for  
15                mounting in a cylinder of an internal combustion engine (not shown), with a connection to a high-voltage (HV) spring 31. Spark plug 30 includes an electrically-conductive, centrally-disposed electrode 32 having a first, high-voltage end 34 and a second, opposing end 36. Spring 31 engages electrode 32, and a high-voltage (HV) terminal 33 from the secondary winding. Spark plug 30 further includes a conductive  
20                shell 38, which may be coupled to an electrical ground. Central electrode 32 and conductive shell 38 are separated by electrical insulating material, such as ceramic 39, as known in the art. The lowermost end 36 is spaced apart from a ground strap connected to shell 38 to define a spark gap therebetween.

In addition, Figure 1 shows a pressure sensor 40 associated with  
25                plug 30 that is configured to detect a pressure in the cylinder and generate a corresponding pressure signal. Pressure sensor 40 may comprise a variety of technologies known to those of ordinary skill in the art including but not limited to piezoelectric devices, piezoresistive devices, and strain gauge devices. In the illustrated embodiment, pressure sensor 40 requires a power signal as an input, and  
30                provides a pressure signal as an output. The conventional approach for input/output of these signals is in the form of electrical leads or the like. A problem with this conventional approach as applied to an assembly 10, relates to the mechanism in

which the upper portion of assembly 10 (*i.e.*, that portion contained within housing 22) is coupled to the lower portion (*i.e.*, that portion contained generally within annular shield 24). That is, the upper and lower portions may first be manufactured as subassemblies, but are then coupled together to form the final assembly 10. Using wires or other direct electrical connections, however, would be sensitive to the angular orientation of the upper portion relative to the lower portion. This sensitivity increases the difficulty of making the connection effectively. In accordance with the present invention, an electrical connection mechanism is provided that is essentially insensitive to the relative angular orientations of the upper portion of assembly 10 compared to the lower portion of assembly 10. Elimination of the above-described sensitivity eases manufacturing of the overall assembly 10.

Figure 2A is a partial, section view showing, in greater detail, the inventive connection scheme shown in Figure 1. As shown, pressure sensor 40 is electrically connected via electrical leads 52, 54 to an internal electronics portion 56. In the illustrated embodiment, leads 52 and 54 are configured to carry the power signal and the pressure signal to/from pressure sensor 40. Electronics 56 may comprise a printed circuit board (PCB). In an alternate embodiment, electronics 56 may comprise a multi-layer flex circuit board. A ground plane layer may be disposed adjacent a tube 58. In such alternate embodiment, electrical “leads” 52, 54 may be provided on subsequent, outer layers sandwiched between insulating layers of the multi-layer circuit board to connect electronics 56 to sensor 40.

Figure 2A further shows a generally, annular electrically insulating tube 58 provided to isolate the pressure sensor signal/pressure sensor electronics 56 (and leads) from the relatively high voltage signal that is produced by transformer 12 and carried through the center of the assembly 10 via HV spring 31. In one embodiment, tube 58 comprises high dielectric thermoplastic material.

Figure 2B further shows a first, generally annular ring connector 60, and a second, generally annular ring connector 62. Ring connectors 60, 62 are configured to receive the above-mentioned power and pressure signals. Ring connectors 60, 62 comprise electrically-conductive material such as steel. Further, each ring connector 60, 62 has a respective electrical connection (*e.g.*, a wire) to electronics 56. In one embodiment, at least the lower, second ring 62 is configured

with an interruption 63 in the circumference thereof to allow the electrical connection from the conductive ring 60 to reach electronics 56. Of course, other variations are possible (*e.g.*, insert mold the electrical connections in tube 58 between the rings 60, 62 and electronics 56).

5                   The rings 60, 62 provide a mechanism for electrical connection that is relatively insensitive to the angular orientation of the upper portion of assembly 10 relative to the lower portion of assembly 10, as described above. Ring connector 60, 62 provide a contact point for a corresponding pair of electrically conductive leaf spring members (described in greater detail below) that are insert molded in  
10   housing 22, and which ultimately terminate on the controller interface 26.

                  With continued reference to Figure 2A, in addition, a seal 64 may be provided so that when the lower portion of assembly 10 (*i.e.*, that which is shown in Figure 2A) is mechanically coupled to the upper portion of assembly 10 (*i.e.*, that which is contained within housing 22), a generally water and other element  
15   impervious seal may be made. Additionally, a boot 70 is included (omitted in Figure 2A for clarity, but shown in Figures 4 and 5 for completeness) for providing electrical separation between the high-voltage to spark plug 30 and the pressure sense power and output signals. This is described in further detail in connection with Figures 4 and 5. As shown in Figure 2A, seal 64 may contain one or more radially,  
20   outwardly projecting ribs. These ribs may bear on an inside diameter surface of housing 22. To enhance environmental immunity, an encapsulant 59 may be employed, filled up to the level "L" in Figure 2A, which covers electronics 56 and the leads 52, 54 that couple pressure sensor 40 to electronics 56. This is an important feature of the present invention.

25                   Figure 3 is a top view of assembly 10 of Figure 1. Figure 3 will provide a frame of reference for subsequent Figures 4 and 5. As shown in Figure 4, housing 22 includes a first electrically conductive leaf spring member 66, and as shown in Figure 5, a second electrically conductive leaf spring member 68. Each leaf spring member 66, 68 is configured to resiliently engage a respective one of the first  
30   and second ring connectors 60 and 62, over a predetermined circumferential angle taken relative to main axis A. Through the foregoing, leaf spring member 66, 68 are

configured to conduct pressure signal and the power signal to/from the interface 26, and electronics 56.

Referring now to Figure 4 particularly, a partial, section view is shown of assembly 10 taken substantially along the line designated 4-4 in Figure 3. Figure 4 shows the first, electrically-conductive leaf spring member 66 in an engaged position with ring 60.

Referring now to Figure 5 particularly a partial, section view is shown of assembly 10 taken substantially along the line designated 5-5 in Figure 3. Figure 5 shows the second, electrically-conductive leaf spring member 68 in an engaged position with ring 62.

Now with reference to Figures 3, 4, and 5, the first leaf spring member 66 engages the first annular ring connector 60 over a first predetermined circumferential angle relative to axis "A." The second electrically-conductive leaf spring member 68 engages the second annular ring connector 62 over a second predetermined circumferential angle relative to axis "A." In the illustrated embodiment, both the first and second predetermined angles are the same, and are substantially equal to the angle designated  $\theta_3$  in Figure 3, which is about  $360^\circ$ . In alternate embodiments,  $\theta_3$  may be less than  $360^\circ$  since in such alternate embodiments, at least the lower ring connector 62 may contain a small break or interruption (best shown as interruption 63 shown in Figure 2B) to allow a electrical lead or the like to pass through, or, alternatively, to allow some measure of flexure so that the rings can be "snapped" on the insulator tube 58.

Referring now to Figure 3 particularly, the first leaf spring member 66 is disposed at a first angular position taken relative to axis x, the first angular position being designated  $\theta_1$ . Likewise, the second leaf spring member 68 is disposed at a second angular position, relative to the x-axis designated  $\theta_2$ . The second angular position  $\theta_2$  is different from the first angular position  $\theta_1$ . This angular offset of the leaf spring members 66 and 68 serve to reduce interference when the upper portion of assembly 10 is connected to the lower portion of assembly 10.

In addition, leaf spring member 66 is axially (*i.e.*, vertically) offset from second leaf spring member 68 to further reduce interference of the electrical connections. This vertical offset of the leaf spring correspond to the axially offset of

the rings 60, 62, one relative to the other. This axial offset may be accomplished in a variety of ways including, but not limited to, varying the length of the leaf spring members, as well as simply varying the amount that each leaf spring member extends into the cavity where the ring connectors 60, 62 are located.

5                    Leaf spring member 66, and 68 may be insert molded in housing 22. In such case, housing 22 may comprise thermoplastic material suitable for fabrication using a molding process.

                    During assembly, the upper portion of assembly 10 (*i.e.*, that which is contained within housing 22) is slid onto the lower portion of assembly 10 (*i.e.*, that  
10                   which is contained within outer shield 24). Leaf spring members 66, 68 resiliently engage respective ring connectors 60, and 62. Significantly, the relative angular orientation of the upper portion of assembly 10 relative to the lower portion of assembly 10 is not as critical as would otherwise be using conventional connection approaches since each leaf spring ring connector pair are configured to engage one  
15                   another over a predetermined angular (circumferential) range. As described above, such predetermined angular circumferential range can be made quite large, approaching or equal to 360°.

                    Assembly 10 may further include an electrically insulating coil boot 70, which acts to separate the relatively high voltage spark signal from the electrical  
20                   signals used by pressure sensor 40. Boot 70 may comprise silicone material.

                    Although the present invention has been fully described in connection with the preferred embodiment thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being  
25                   included within the scope of the present invention as defined by the appended claims.